Buoyant Asthenosphere Beneath Cascadia Influences Megathrust Segmentation

Great megathrust earthquakes (magnitude 8+) do not typically rupture an entire convergent margin, but rather are limited to one or more along-strike segments. A fundamental question of subduction zone dynamics and hazard assessment is what physical properties or dynamic processes govern megathrust segmentation. We present teleseismic P-wave tomography results for the Cascadia subduction zone and explore the relationship between mantle structure and megathrust segmentation. We utilize delay times from the onshore-offshore amphibious Cascadia Initiative array and existing dense datasets for the western US providing enhanced ray coverage beneath the forearc and incoming oceanic plate. Our tomographic method allows for 3D starting models, non-linear raytracing, finite-frequency kernels, and explicitly includes elevation. By selecting a starting model derived from existing surface wave studies, we can account for first order structure in the upper 50 km using independent observations rather than inversion driven station statics. We image two localized low-velocity anomalies beneath the subducting slab in northern and southern Cascadia. This is in contrast to previous results suggesting margin wide low-velocity anomalies. The segmentation we observe in the oceanic asthenosphere beneath the subducting plate correlates along-strike with regions of increased plate locking and greater occurrence of episodic tremor and slip. We attribute the anomalous asthenospheric velocities to independent mantle upwellings associated with hotspot-derived material in northern Cascadia and fragmentation processes at a diffuse plate-boundary in southern Cascadia. We suggest that anomalies represent regions of partial melt and possibly increased temperatures resulting in excess buoyancy sub-slab. We infer that sub-slab buoyancy modulates coupling at the thrust interface, thereby contributing to the localization of subduction zone segmentation.